EYE FEATURE EXTRACTION FOR FETAL ALCOHOL SYNDROME SCREENING

T.S. Douglas[1], F. Martinez[1], E.M. Meintjes[1], C.L. Vaughan[1], D. Viljoen[2]
[1]MRC/UCT Medical Imaging Research Unit, Department of Human Biology, University of Cape Town, South Africa
[2]Department of Human Genetics, South African Institute for Medical Research, Johannesburg, South Africa

Abstract-Conventional screening for Fetal Alcohol Syndrome in children involves time-consuming and intrusive facial measurements. We are developing an alternative method that will allow automatic measurement of the relevant points from a pair of stereo photographs. This paper describes a method for automatic eye extraction from such photographs, using genetic algorithms to match eye templates to face images.
Keywords – eye feature extraction, fetal alcohol syndrome, genetic algorithm

I. INTRODUCTION

Fetal Alcohol Syndrome (FAS) is a consequence of the teratogenic effects of excessive maternal alcohol ingestion on the fetus *in utero*, and is the most common preventable cause of mental retardation worldwide [1], [2]. FAS is characterized by growth retardation, central nervous system abnormalities, facial dysmorphology, and other malformations. Atrophy and flattening of the frontal lobes of the brain are thought to cause the characteristic facial features, mainly contraction of the middle third of the face.

There are no biological markers for FAS. Diagnosis requires a positive maternal history of heavy alcohol ingestion during pregnancy in addition to the presence of the characteristic features, confirmed by specialists with experience and expertise in dysmorphology. Conventional assessment of facial dysmorphology includes time-consuming and intrusive distance measurements on the face. The relevant points and distances are depicted in Fig. 1. We are developing an alternative method that will allow automatic measurement of the relevant points from a pair of stereo photographs of 6 to 7-year old children. This paper describes the use of genetic algorithms (GAs) to find eye features in these photographs.

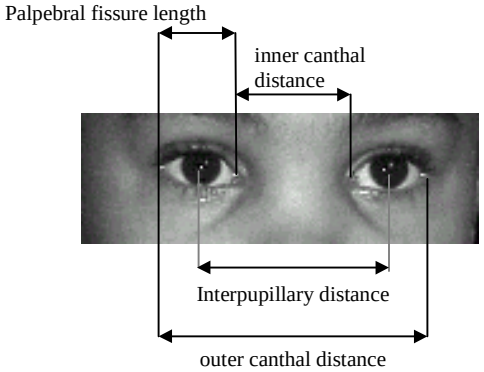

Figure 1. Distance measurements for FAS screening

A. Image Acquisition

Two photographs are taken simultaneously with digital cameras mounted about 40 cm apart at a fixed distance from a reference frame within which the children place their heads (Fig. 2). Markers on the reference frame allow the images to be calibrated and placed in a three-dimensional co-ordinate frame. If the eyes are located and the relevant points identified on each of the two images, the required distances can be calculated.

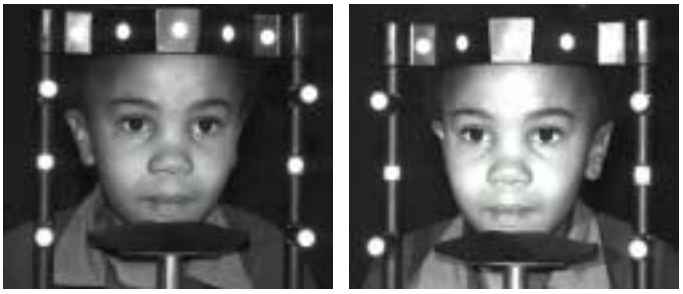

Figure 2. Stereo photographs using reference frame

B. Genetic Algorithms

GAs are adaptive search procedures that perform function optimization based on the principles of evolution by natural selection [6]. They are capable of locating good approximate solutions in large search spaces without becoming trapped in local minima.

The function being optimized by the GA is known as the objective function or fitness function, and its range is called the search space. The parameters of the optimization problem are represented by binary strings called genes that are concatenated into chromosomes representing potential solutions. If γ_i denotes a gene representing parameter i, then the chromosome $c = \gamma_1,\gamma_2,\ldots,\gamma_n$, and a population $P = \{c_1, c_2,\ldots, c_k\}$, where k denotes the population size.

The initial population of chromosomes with which the search begins, is generated randomly. Each member of the population is evaluated with the fitness function and assigned a fitness level. The population is then iteratively updated through a reproduction strategy that favours the fittest chromosomes, until the fitness function is maximized or the desired number of generations has been reached.

GAs are employed here to detect eyes in an image by finding the optimal match firstly between a circular iris template and the image, and then between the sclera template, described by cubic splines, and the image.

Report Documentation Page

Report Date	Report Type	Dates Covered (from... to)
25 Oct 2001	N/A	-

Title and Subtitle Eye Feature Extraction for Fetal Alcohol Syndrome Screening	**Contract Number**
	Grant Number
	Program Element Number
Author(s)	**Project Number**
	Task Number
	Work Unit Number
Performing Organization Name(s) and Address(es) MRC/UCT Medical Imaging Research Unit Department of Human Biology University of Cape Town South Africa	**Performing Organization Report Number**
Sponsoring/Monitoring Agency Name(s) and Address(es) US Army Research, Development & Standardization Group (UK) PSC 802 Box 15 FPO AE 09499-1500	**Sponsor/Monitor's Acronym(s)**
	Sponsor/Monitor's Report Number(s)

Distribution/Availability Statement
Approved for public release, distribution unlimited

Supplementary Notes
Papers from 23rd Annual International Conference of the IEEE Engineering in Medicine and Biology Society, October 25-28, 2001, held in Istanbul, Turkey. See also ADM001351 for entire conference on cd-rom.

Abstract

Subject Terms

Report Classification unclassified	**Classification of this page** unclassified
Classification of Abstract unclassified	**Limitation of Abstract** UU

Number of Pages
4

C. Eye Templates

Yuille et al. [3] proposed and Xie et al. [4] modified a method of eye feature extraction based on deformable templates in which the iris is modelled by a circle and the eyelids by 2 parabolic sections. Esme et al. [5] used genetic algorithms as a search strategy to find eye contours modelled by parabolic templates.

We propose an algorithm in which the iris is modelled by a circle as suggested in [3] and [4], but the eye by a set of cubic splines (one representing the upper and one the lower eyelid). Each cubic spline is described by 4 control points, and the end points are common. The eye template is shown in Fig. 3.

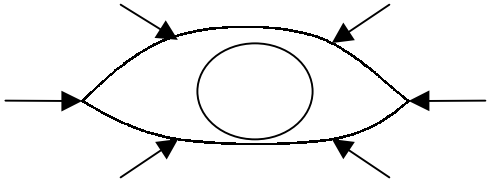

Figure 3. Eye template. The circle is specified by its radius and the co-ordinates of its centre. The arrows indicate cubic spline control points.

D. Pre-processing

Since the face is always photographed in a fixed position, an image window in which each eye can be expected to appear can be specified in order to reduce the search space. Each eye is treated separately.

Yuille et al. [3] and Xie et al. [4] used search strategies based on steepest descent and the Levenberg-Marquardt method respectively, operating on complex energy functions consisting of terms due to valley, edge, peak, image and internal potentials, to find the desired points in the eye. Esme et al. [5] used a fitness function based on fused peak, valley and edge maps. Our fitness function is based only on peak and valley maps.

The peak and valley maps [5] of the image are used to fit the templates to the image. They are calculated as shown in (1) and (2).

$$I_v(x,y) = \frac{u(I_w(x,y) - I(x,y)) \times |I_w(x,y) - I(x,y)|}{I_w(x,y)} \cdot 255 \quad (1)$$

$$I_p(x,y) = \frac{u(I(x,y) - I_w(x,y)) \times |I_w(x,y) - I(x,y)|}{I_w(x,y)} \cdot 255 \quad (2)$$

The valley map (I_v) selects dark regions in the image, such as the iris. It compares pixels in an image window (I_w) with the window average, assigns the value '0' to those pixels greater than the window average, and assigns to those pixels less than the window average a value proportional to the difference between the pixel and the average. The new pixel values are normalized to the range 0 to 255. I denotes the original image, and u denotes the unit step function.

The peak map (I_p) selects bright regions in the image, such as the sclera, in a similar manner: it assigns the value '0' to those pixels less than the window average, and assigns to those pixels greater than the window average a value proportional to the difference between the pixel and the average.

E. Matching the Iris

1) *Parameters*: The parameters being optimized by the GA and which are therefore encoded in the chromosomes are the radius and centre (x- and y-co-ordinates) of the circle.

2) *Initial population*: An initial random population of chromosomes is generated.

3) *Fitness function*: The iris appears as a bright circular area in the valley image I_v. The circular template is filled in so that it becomes a disc I_d. The correlation coefficient r of this disc with the valley image is the fitness function f, as shown in (3) and (4). A and B in (3) denote any two images, while $\overline{A}$ and $\overline{B}$ denote the mean pixel intensity in these images.

$$r(A,B) = \frac{\sum_j \sum_k (A_{j,k} - \overline{A})(B_{j,k} - \overline{B})}{\sqrt{\left(\sum_j \sum_k (A_{j,k} - \overline{A})^2\right)\left(\sum_j \sum_k (B_{j,k} - \overline{B})^2\right)}} \quad (3)$$

$$f = r(I_v, I_d) \quad (4)$$

4) *Reproduction:* One third of the chromosomes in each new generation are those with the highest fitness values from the previous generation. Another third of the new generation is obtained by performing simple crossover between randomly selected pairs of strings from the previous generation with no weighting based on string fitness, and the final third consists of new randomly generated chromosomes. The population size remains constant.

F. Matching the Sclera

1) Parameters: Once the iris has been localized, a smaller window, within which the sclera is expected to be located, is defined around the iris centre. The parameters being optimized are the locations (x- and y-co-ordinates) of the 6 cubic spline control points that specify the eye template.

2) *Initial Population:* The initial population is generated randomly as with the iris.

3) *Fitness function*: The sclera appears as a bright region in the peak image I_p. The area within the 2 cubic splines that form the eye template is filled in and the iris is removed from it so that only the sclera remains. This template is multiplied point-wise with a gaussian of the same size so as

to simulate the effect found in images of the eye and the peak map where the intensity of the sclera gradually decreases towards the eye corners.

The valley image, in which the sclera appears dark, is also used in the fitness function, which is shown in (5). I_s denotes

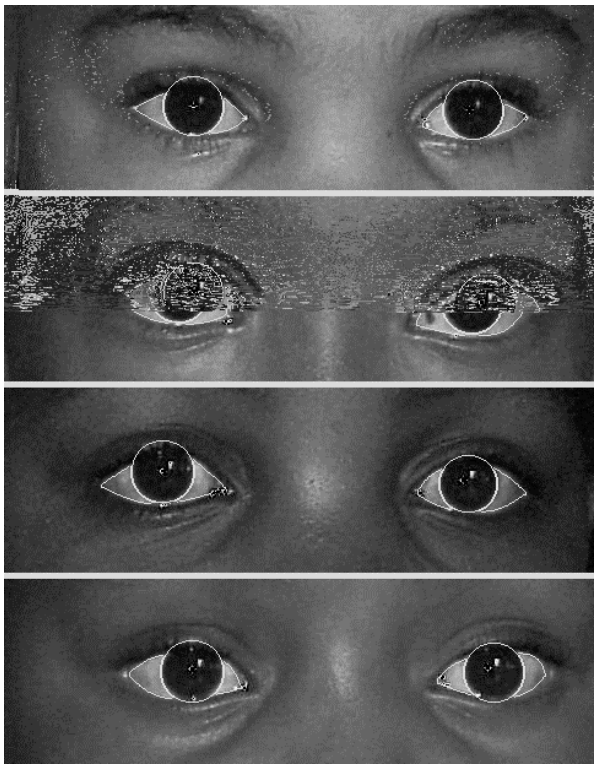

Figure 8. Results for four different sets of eyes.

IV. CONCLUSION

We have presented an algorithm for eye extraction that we intend using as part of a method of screening children for the facial features characteristic of fetal alcohol syndrome. The accuracy at which the desired points on the eye (corners, iris centre) can be located is yet to be determined. Future work includes comparison of the performance of this algorithm with manual identification of the relevant points.

ACKNOWLEDGMENT

This work was conducted with the aid of a grant from the South African Medical Research Council.

REFERENCES

[1] D.Viljoen, "Fetal alcohol syndrome", *South African Medical Journal*, vol. 89(9), pp. 958-960, 1999.
[2] J. Croxford, D. Viljoen, "Alcohol consumption by pregnant women in the Western Cape," *South African Medical Journal*, vol. 89(9), pp. 962-965, 1999.
[3] A.L. Yuille, P.W. Hallinan, D.S. Cohen, "Feature extraction from faces using deformable templates," *Int. J. Computer Vision*, vol. 8(2) pp. 99-111, 1992.
[4] X. Xie, R. Sudharkar, H. Zhuang, "On improving eye feature extraction using deformable templates," *Pattern Recognition*, vol. 27(6), pp. 791-799, 1994.
[5] B. Esme, B. Sanur, E. Anarum, "Facial feature extraction using genetic algorithms," *Signal Processing VIII, Theories and Applications, Proceedings of EUSIPCO-96*, 1996.
[6] D. E. Goldberg, *Genetic Algorithms in Search, Optimization, and Machine Learning*, New York:Addison Wesley, 1989.